Time Series Characteristics of the ChiNext Board Index and the SSE Science and Technology Innovation Board 50 Index in China's Growth Enterprise Market

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1 Introduction

On October 30, 2009, the Chinese version of the NASDAQ, the ChiNext Board, was launched on the Shenzhen Stock Exchange. The ChiNext Board provides financing for self-initiated innovative and fast-growing firms. In addition, 25 companies were listed on the Shanghai Stock Exchange's (SSE's) growth market, named the Science and Technology Innovation Board, on July 22, 2019. The SSE Science and Technology Innovation Board was established to both support innovation and promote capital market reform in China. In this study, we used data on the ChiNext Board Index for the ChiNext Board market and the STAR50 for the Science and Technology Innovation Board market to characterize the timeseries data for these new stock markets.

In financial time series analysis, the focus is often on the following four stylized facts for model specification, estimation, and forecasting. (i) Fat tails: The distribution of rate of return follows a thicker distribution than the normal distribution. (ii) Volatility clustering: A period of high (low) volatility follows an increase (decrease) in volatility. (iii) Leverage effects: there is negative correlation between stock price fluctuations and volatility. (iv) Long memory: autocorrelation of time series data decreases slowly and has long-term effects. Accordingly, in this paper, we use the ARCH-type model, which frequently appears in financial time series analysis and can be easily extended consistent with the above stylized facts, to capture the characteristics of time series data.

It is also well known that the distribution of returns has a fatter tail than the normal distribution. For this reason, the error term in ARCH-type models is often assumed to be other than normally distributed. In addition, many previous studies have shown that a distribution with higher kurtosis than the normal distribution is more applicable to the error term. Therefore, in this study, in addition to the standardized normal distribution, the standardized Student- t distribution, the generalized error distribution (GED), and the standardized skewed-Student distribution were used as the distribution of the error term. Specifically, the volatilities of the ChiNext Board Index and the STAR50 were analyzed using a model based on these assumptions

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. We also use the multivariate GARCH (MGARCH) model to examine the dynamic conditional correlation between the growth enterprise indices and the composite stock indices of the Shenzhen and Shanghai stock markets.

As part of this empirical analysis, we conducted empirical tests using daily data from June 2, 2010 to July 29, 2022 for the ChiNext Board Index and data from July 24, 2020 to July 29, 2022 for the STAR50. This empirical analysis showed the following three facts as its main results. (1) The shocks to ChiNext's rate of return and STAR50's rate of return volatility are highly persistent. (2) For time series analysis of ChiNext, it is effective to use a distribution with a thicker base than the normal distribution. (3) The dynamic conditional correlation is positive for the ChiNext Board Index and the Shenzhen Composite Index, and negative for the STAR50 and the Shanghai Composite Index[1].

The remainder of the paper is organized as follows. Section 2 describes the data of the ChiNext Board Index and the STAR50. Section 3 describes the analytical model used in this study and the distribution of the error term. Section 4 discusses the empirical results. The final section, Section 5, provides a summary and discusses future issues.

2 Data from ChiNext Board Index and STAR50

2.1 ChiNext Board Index

The ChiNext Board Index comprehensively and objectively reflects the price movements of all stocks listed on the ChiNext Board, which is an independent market composed of stocks of independent innovative companies and growing venture companies. Compiling of the index began on June 1, 2010.

Data were obtained from Bloomberg and the data period is from June 2, 2010[2] to July 29, 2022 (see Figure 1[3]). The rate of return was calculated as the percentage change in the closing price of each index (see Figure 2). The sample period is from June 3, 2010 to July 29, 2022, and the sample size is 2,954. As summary statistics of the data, mean, standard deviation, skewness, excess kurtosis, maximum, minimum, and normality test statistics are given in Table 1. For the rate of return of the ChiNext Board Index, the excess kurtosis exceeded 0, and the normality test was significant, indicating that the distribution of the rate of return of the ChiNext Board Index has a thicker base than the normal distribution. Table 1 also gives summary statistics for the Shenzhen Composite Index[4]. A histogram and the density function of the rate of return on the ChiNext Board Index are depicted in

1) Shanghai Stock Exchange Composite Index: SSE Composite Index

2) The first day of trading for the ChiNext Board Index

3) In this study, all figures were created by PcGive (statistical and time series analysis software).

4) The Shenzhen Composite Index is a market capitalization-weighted index (floating shares are excluded). The index is calculated using April 3, 1991 as the base date, setting the index value on that date as 100.

Figure 3 with the normal approximation superimposed. In the figure, $N(s=1.964)$ indicates that the normal approximation follows the normal distribution $N(-0.035, 1.964^2)$, i.e., with mean -0.035 and variance 1.964^2, from Table 1. Figure 4 depicts the autocorrelation of $|R_t|$. From Figure 4, we can see that the decay of autocorrelation of $|R_t|$ is very slow. This suggests that the series of $|R_t|$ has long-term memory.

2.2 STAR50

The SSE Science and Technology Innovation Board, commonly known as the STAR Board, is a

Table 1: Summary statistics for daily rates of return for the ChiNext and the SZCOMP
June 3, 2010 – July 29, 2022, No. of Obs. 2,954

	Mean	Std. Dev.	Skewness	Exc. Kurtosis	Max.	Min.	Normality Test
ChiNext	-0.035	1.964	0.482^{**}	1.944^{**}	9.332	-6.915	225.2^{***}
	(0.036)		(0.045)	(0.090)			
SZCOMP	0.026	1.595	-0.827^{**}	3.444^{**}	6.320	-8.789	379.8^{***}
	(0.029)		(0.045)	(0.090)			

Numbers in parentheses indicate standard errors. Letting T be the number of samples and $\hat{\sigma}$ be the standard deviation, the standard errors of mean, skewness, and kurtosis are respectively $\hat{\sigma}/\sqrt{T}$, $\sqrt{6/T}$, and $\sqrt{24/T}$.

** Significant at the 5% level. *** Significant at the 1% level.

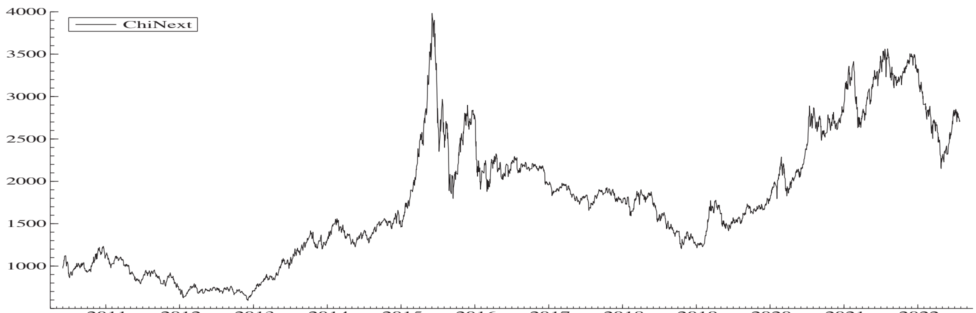

Figure 1: The closing price of the ChiNext (June 2, 2010 – July 29, 2022)

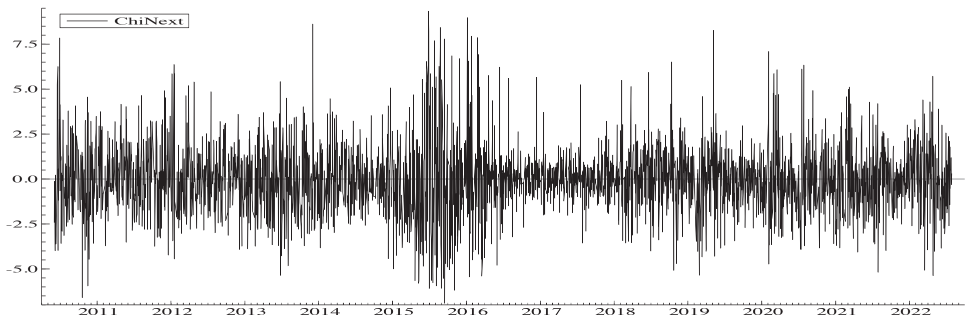

Figure 2: Returns for the ChiNext (June 3, 2010 – July 29, 2022)

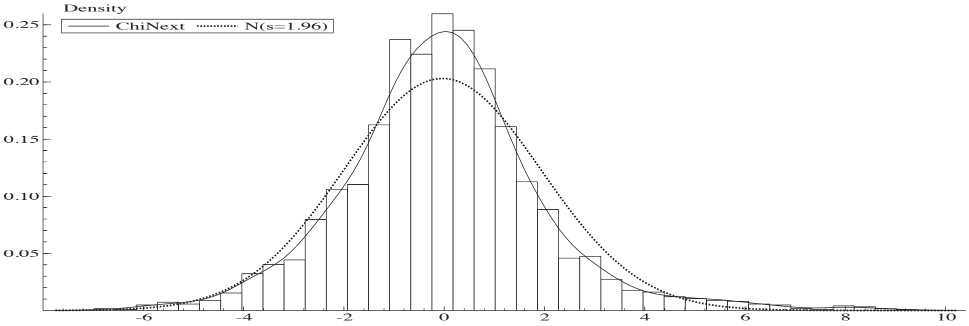

Figure 3: Histogram of ChiNext returns and its normal approximation

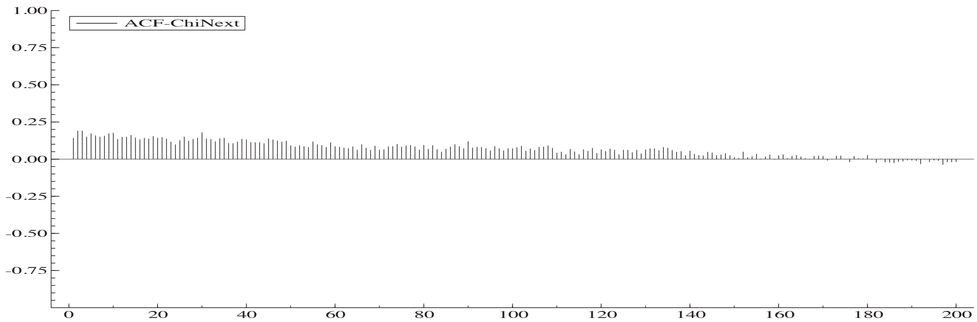

Figure 4: ACF for ChiNext $|R_t|$

stock market that opened on the Shanghai Stock Exchange in June 2019. The role of the STAR Board is to support innovation for economic development, encourage capital market performance, and promote the joint development of the Shanghai International Financial Center and the Science and Technology Innovation Center. The rationale for the listed companies is that they are companies with cutting-edge science and technology, and specific industrial fields are defined.

The associated index measures 50 stocks listed on the SSE Science and Technology Innovation Board with large market capitalization and high liquidity. The index is calculated with December 31, 2019 as the base date, setting the index value on that date as 1,000. The index is calculated by a market capitalization-weighted method adjusted for the ratio of floating shares.

Data were obtained from Bloomberg and the data period is from July 23, 2020[5)] to July 29, 2022 (see Figure 5). The rate of return was calculated as the percentage change in the closing price of each index (see Figure 6). The sample period is from July 24, 2010 to July 29, 2022, with a sample size of 490. Summary statistics of the data are given in Table 2. The rate of return of the STAR50 had excess kurtosis exceeding 0, and the normality test was significant, indicating that the distribution of the rate of return of STAR50 has a thicker base than the normal distribution. Table 2 also gives summary

5) The first day of trading for the STAR50

statistics for the Shenzhen Composite Index[6]. A histogram and the density function of the rate of return on STAR50 are depicted in Figure 7 with the normal approximation superimposed. In the figure, $N(s=1.764)$ indicates that the normal approximation follows the normal distribution $N(-0.061, 1.764^2)$, i.e., mean -0.003 and variance 1.764^2, from Table 2.

Table 2: Summary statistics for daily rates of return for the STAR50 and the SHCOMP July 24, 2020 – July 29, 2022, No. of Obs. 490

	Mean	Std. Dev.	Skewness	Exc. Kurtosis	Max.	Min.	Normality Test
STAR50	-0.061 (0.080)	1.764	0.083 (0.111)	0.871** (0.221)	7.008	-7.275	14.70***
SHCOMP	-0.003 (0.046)	1.023	-0.682** (0.111)	2.700** (0.221)	3.425	-5.268	56.73***

Numbers in parentheses indicate standard errors. Letting T be the number of samples and $\hat{\sigma}$ be the standard deviation, the standard errors of mean, skewness, and kurtosis are respectively $\hat{\sigma}/\sqrt{T}$, $\sqrt{6/T}$, and $\sqrt{24/T}$.
** Significant at the 5% level. (iii) *** Significant at the 1% level.

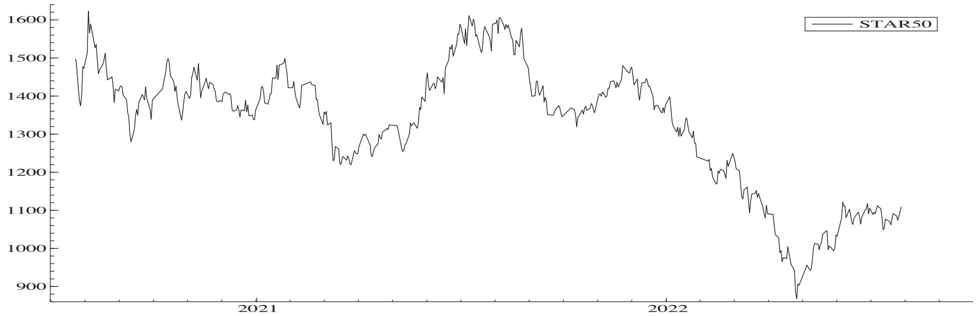

Figure 5: The closing price of the STAR50 (July 23, 2020 – July 29, 2022)

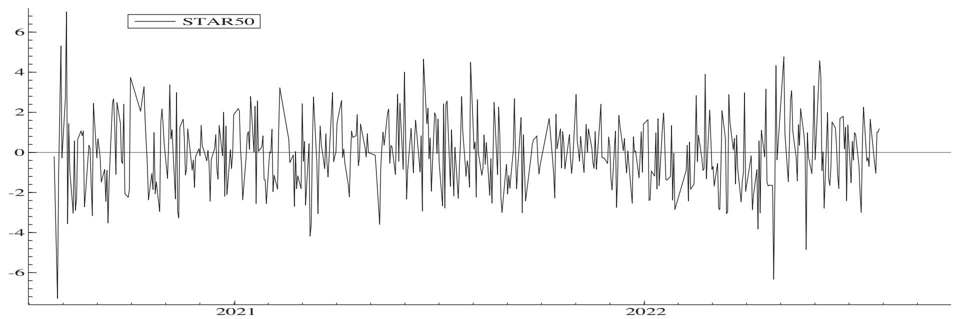

Figure 6: Returns for the STAR50 (July 24, 2020 – July 29, 2022)

6) The Shenzhen Composite Index is a market capitalization-weighted index (floating shares are excluded). The index is calculated using April 3, 1991 as the base date, setting the index value on that date as 100.

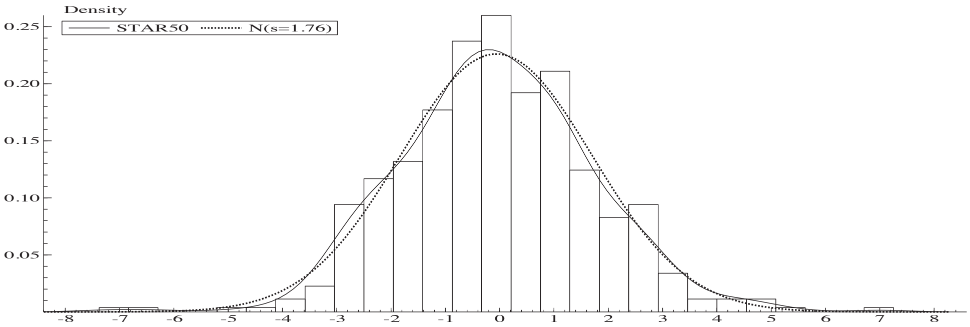

Figure 7: Histogram of STAR50 returns and its normal approximation

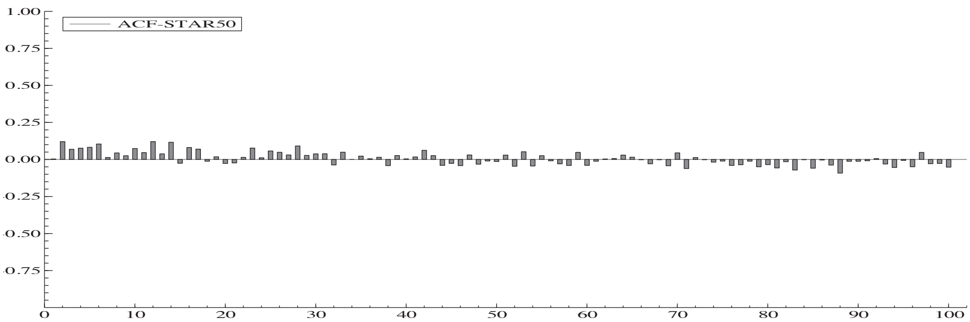

Figure 8: ACF for STAR50 $|R_t|$

2.3 Unit Root Test

In this study, the Augmented Dickey–Fuller (ADF) test was used[7]. Two formulations of the model for the unit root test were used, one without trend and the other with trend. The ADF(n) test was performed using the following formulation:

$$\Delta x_t = \alpha + bx_{t-1} + \sum_{i=1}^{n} \gamma_i \Delta x_{t-1} + u_t, \tag{2.1}$$

$$\Delta x_t = \alpha + \mu t + bx_t -_1 + \sum_{i=1}^{n} \gamma_i \Delta x_{t-1} + u_t \text{ (with trend)}. \tag{2.2}$$

The order of the lag for the ADF test is from the first order to the third order. From Table 3, the order of lag for the test is ADF(1) with lag 1 for the ChiNext Board Index and Shenzhen Composite Index, and ADF(2) with lag 2 for the STAR 50 and Shanghai Composite Index. The critical values are those calculated by Mackinnon (1991). The null hypothesis that there is a unit root for each rate of return was rejected both in the absence and presence of a trend.

7) For details on the ADF test, see Dickey and Fuller (1981).

Table 3: Unit root test

ChiNext

Lag	ADF Statistics	b	S.E.	AIC	with trend ADF Statistics	b	S.E.	AIC
3	-27.31^{***}	0.022	1.960	1.348	-27.30^{***}	0.022	1.960	1.348
2	-31.24^{***}	0.029	1.960	1.347	-31.23^{***}	0.029	1.960	1.348
1	-38.81^{***}	0.018	1.960	1.347	-38.81^{***}	0.018	1.960	1.347
0	-51.48^{***}	0.054	1.961	−	-51.48^{***}	0.054	1.960	−

SZCOMP

Lag	ADF Statistics	b	S.E.	AIC	with trend ADF Statistics	b	S.E.	AIC
3	-26.56^{***}	0.067	1.593	0.9328	-26.55^{***}	0.067	1.593	0.9335
2	-30.34^{***}	0.070	1.593	0.9322	-30.33^{***}	0.070	1.593	0.9328
1	-37.73^{***}	0.050	1.593	0.9319	-37.73^{***}	0.050	1.593	0.9326
0	-50.87^{***}	0.065	1.593	−	-50.86^{***}	0.065	1.339	−

STAR50

Lag	ADF Statistics	b	S.E.	AIC	with trend ADF Statistics	b	S.E.	AIC
3	-11.78^{***}	−0.043	1.738	1.115	-11.78^{***}	−0.045	1.739	1.119
2	-13.51^{***}	−0.019	1.736	1.112	-13.51^{***}	−0.021	1.738	1.115
1	-14.96^{***}	0.061	1.741	1.115	-14.96^{***}	0.060	1.743	1.119
0	-20.96^{***}	0.049	1.740	−	-20.94^{***}	0.049	1.741	−

SHCOMP

Lag	ADF Statistics	b	S.E.	AIC	with trend ADF Statistics	b	S.E.	AIC
3	-11.94^{***}	−0.108	1.011	0.033	-11.97^{***}	−0.038	1.012	0.035
2	-13.86^{***}	−0.090	1.010	0.029	-13.88^{***}	0.006	1.011	0.031
1	-15.39^{***}	0.003	1.014	0.034	-15.41^{***}	0.036	1.014	0.037
0	-22.35^{***}	−0.015	1.013	−	-22.36^{***}	−0.020	1.013	−

The critical values for the case of no trend are 2.86 for a significance level of 5% and −3.44 for a significance level of 1%, whereas the critical values for the case of trend are − 3.41 for a significance level of 5% and −3.97 for a significance level of 1%.
***Significant at the 1% level.

3 Analytical Model

3.1 GARCH-M Model

In this study, GARCH-M (in-the-mean), based on the GARCH model of Bollerslev (1986), was used to analyze time series data. Since many empirical studies have shown that increasing the order of the volatility fluctuation process does not improve performance, the GARCH(1,1)-M model was used in the present study as well[8). Letting R_t be the rate of return at time t in a discrete-time economy, the process of the rate of return is as follows:

$$R_t = \mu + \lambda\sigma + \epsilon_t, \tag{3.1}$$

$$\epsilon_t = \sigma_t z_t, \sigma_t > 0, \tag{3.2}$$

$$z_t \sim i.i.d., E[z_t] = 0, Var[z_t] = 1. \tag{3.3}$$

The constant term in equation (3.1) is the expected rate of return, λ is the risk premium, and ϵ_t is the error term. No autocorrelation in the rate of return was assumed. Note that $i.i.d.$ denotes that a distribution is independent and identically distributed, and that $E[\cdot]$ and $Var[\cdot]$ denote the expected value and variance, respectively[9). The volatility σ_t^2 is formulated as a linear function of the squares of the past forecast error and the past volatility[10):

$$\sigma_t^2 = \omega + \alpha\,\epsilon_{t-1}^2 + \beta\sigma_{t-1}^2. \tag{3.4}$$

Here, we assume $\omega, \alpha, \beta > 0$ to guarantee non-negativity of volatility[11). The process of volatility is assumed to be stationary with $\alpha + \beta < 1$ to guarantee stationarity.

It is known that the distribution of return on assets has a fatter tail than the normal distribution. In addition, many previous studies have shown that a distribution with higher kurtosis than the normal distribution is more applicable as the distribution of the error term. Therefore, in this study, we used

8) Usually, the order selection of the GARCH model should be based on two information criteria, Akaike's Information Criterion (AIC) and Schwart's Information Criterion (SIC). When the parameters are estimated by the maximum likelihood method, AIC and SIC are calculated as follows:

$$AIC = -2\ln L + 2n,$$
$$SIC = -2\ln L + k\ln T.$$

$\ln L$ is the log-likelihood evaluated under the estimated parameters, k is the number of estimated parameters, and T is the sample size.

9) Table 1 shows that the mean values of the ChiNext Board Index and STAR50 rates of return are negative, but the standard error values indicate that this is not statistically significant in either case. The null hypothesis "H_0 : mean $\mu = 0$" cannot be rejected at significance levels of 1%, 5%, and 10%, and there seems to be no problem in estimating the mean of each stock index as 0. Therefore, it is appropriate to assume that the expected value of z_t is 0 in equation (3.3).

10) The general GARCH(p, q) model is expressed as follows:

$$\sigma_t^2 = \omega + \sum_{i=1}^{p}\alpha_i\,\epsilon_{t-i}^2 + \sum_{j=1}^{q}\beta_j\sigma_{t-j}^2.$$

11) In the case of GARCH(1,1), the non-negativity constraint is a necessary and sufficient condition. However, in the case of higher-order GARCH(p, q), the non-negativity constraints on the parameters can be relaxed. For details, see Nelson and Cao (1992).

the standard normal distribution, the standardized Student-t distribution, the GED, and the standardized skewed-Student t distribution[12] as the distributions of z_t[13].

(i) Student-t distribution:

The density function $f_{(t)}(z_t; \nu)$ of the standardized Student-t distribution is given by

$$f_{(t)}(z_t : \nu) = \frac{\Gamma((\nu+1)/2)}{\Gamma(\nu/2)\sqrt{\pi(\nu-2)}}\left(1+\frac{z_t^2}{\nu-2}\right)^{-(\nu+1)/2}, \quad \nu > 2, \tag{3.5}$$

where ν denotes the degrees of freedom. The Student-t distribution is symmetric about 0, and the kurtosis is greater than 3 for $\nu>4$[14] Also, when $\nu \to \infty$, the density function converges to the density function of the standard normal distribution.

(ii) GED:

The density function $f_{(GED)}(z_t : \nu)$ of the GED is given by

$$\begin{aligned} f_{(GED)}(z_t : \nu) &= \frac{\nu \exp\left(-\frac{1}{2}|z_t/\lambda_\nu|^\nu\right)}{\lambda_\nu 2^{(1+\frac{1}{\nu})}\Gamma(1/\nu)}, \quad \nu > 0, \\ \lambda_\nu &= \sqrt{\frac{\Gamma(1/\nu)\, 2^{(-2/\nu)}}{\Gamma(3/\nu)}}, \end{aligned} \tag{3.6}$$

where ν is a parameter indicating the thickness of the tails. When $\nu = 2$, z_t follows a standard normal distribution, whereas it follows a distribution with thicker tails when $\nu<2$ and one with thinner tails when $\nu>2$.

(iii) skewed-Student t distribution:

The density function $f_{(skt)}(z_t : \nu, \xi)$ of the standardized skewed-Student t distribution is given by

$$\begin{aligned} f_{(skt)}(z_t : \nu, \xi) &= \frac{\Gamma((\nu+1)/2)}{\Gamma(\nu/2)\sqrt{\pi(\nu-2)}}\left(\frac{2s}{\xi+1/\xi}\right)\left(1+\frac{(sz_t+m)^2}{\nu-2}\xi^{-2I_t}\right)^{-(\nu+1)/2}, \quad \nu > 2, \\ I_t &= \begin{cases} 1 & \text{if } z_t \geq -\frac{m}{s} \\ -1 & \text{if } z_t < -\frac{m}{s} \end{cases}. \end{aligned} \tag{3.7}$$

Here, ν denotes the degrees of freedom, which determines the thickness of the distribution, and ξ is an

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12) Giot and Laurent (2004) analyzed stock indices and foreign exchange rates by applying the skewed-Student t distribution proposed by Fernández and Steel (1998) to value at risk (VaR) based on an ARCH-type model.

13) Other studies that have applied distributions thicker than the available normal distributions to ARCH-type models include Bollerslev*et al*. (1994), with the generalized t distribution, and Michelfelder (2005), with the skewed GED.

14) The kurtosis Kt of the Student-t distribution with ν degrees of freedom is as follows:

$$\begin{aligned} K_t &= \frac{3(\nu-2)}{\nu-4} \\ &= 3 + \frac{6}{\nu-4}, \quad \nu > 4. \end{aligned}$$

Therefore, the kurtosis is always larger than 3.

asymmetry parameter determining the distortion of the distribution. In addition, m and s are as follows:

$$m = \frac{\Gamma((\nu+1)/2)\sqrt{\nu-2}}{\sqrt{\pi}\,\Gamma(\nu/2)}\left(\xi - \frac{1}{\xi}\right), \tag{3.8}$$

$$s = \sqrt{\left(\xi + \frac{1}{\xi} - 1\right) - m^2}. \tag{3.9}$$

Here, if $\xi = 1$, or $\ln(\xi) = 0$, then the distribution is symmetric and equal to the Student-t distribution. The right tail of the distribution becomes thicker when $\xi > 1$, or $\ln(\xi) > 0$, whereas the left tail of the distribution becomes thicker when $\xi < 1$, or $\ln(\xi) < 0$.

If z_t follows the standard normal distribution, the normalized Student-t distribution, the GED, or the normalized skewed-Student t distribution, then this is respectively expressed as follows for z_t in equation (3.3):

$$z_t \sim i.i.d.N\,(0, 1), \tag{3.10}$$

$$z_t \sim i.i.d.t\,(0, 1, \nu), \tag{3.11}$$

$$z_t \sim i.i.d.GED\,(0, 1, \nu), \tag{3.12}$$

$$z_t \sim i.i.d.skt\,(0, 1, \nu, \xi), \tag{3.13}$$

Parameters are estimated by maximizing the log-likelihood function using the statistical analysis software G@RCH 7.0 OxMetrix.

3.2 Multivariate GARCH Model

Engle's (2002) dynamic conditional correlation GARCH (DCC-GARCH) is defined as follows:

$$H_t = D_t R_t D_t, \tag{3.14}$$

$$D_t = diag(\sigma_{11t} \ldots \sigma_{NNt}), \tag{3.15}$$

$$\sigma^2_{iit} = \omega_i + \alpha_i\,\epsilon^2_{i,t-1} + \beta_i \sigma^2_{ii,t-1},\ i = 1, \ldots, N. \tag{3.16}$$

$$R_t = diag(q^{1/2}_{11,t} \cdots q^{1/2}_{NN,t})\,Q_t\,diag(q^{1/2}_{11,t} \cdots q^{1/2}_{NN,t}). \tag{3.17}$$

Here, the $N \times N$ symmetric positive definite matrix $Q_t = (q_{ij,t})$ is given by

$$Q_t = (1 - \alpha - \beta)\bar{Q} + \alpha u_{t-1}\,u'_{t-1} + \beta Q_{t-1}, \tag{3.18}$$

where $\bar{Q}$ is the $N \times N$ unconditional variance matrix of u_t, and α and β are non-negative scalar parameters satisfying $\alpha+\beta<1$. We can be estimated consistently using two-step estimation.

4 Empirical Results

The empirical results of this study for the GARCH-M model are given in Table 4. These results can be summarized as follows. Regarding the ChiNext Board Index, for the parameter μ, the estimates are statistically significant for all distributions. The estimated values of λ indicating the risk premium are -0.167, -0.190, -0.189, and -0.175 for the normal, t distribution, GED, and skewed-Student t distribution, respectively, and all are statistically significant. For ω, the estimates are also statistically significant for all distributions, as are those of β, a parameter indicating the persistence of volatility. For ν, the degrees of freedom, the estimates are 8.132 and 9.162 for the t distribution and skewed-Student t, respectively, and are statistically significant and both satisfy $\nu>4$. In the case of the GED, the estimated value of ν is 1.484, which is also statistically significant and satisfies $\nu<2$. These results show that the rate of return of the ChiNext Board Index follows a distribution with a thicker base than the normal distribution. The estimated value of the asymmetric parameter $\ln(\xi)$ is statistically significant at 0.116, indicating that the right tail of the profitability distribution of the ChiNext Board Index is thick.

In the case of the STAR50, for μ, λ, and ω, the estimates are not statistically significant for any of

Table 4: Parameter estimation results for the GARCH(1,1)-M model

	ChiNext Board Index				STAR50			
	N	t	GED	skt	N	t	GED	skt
μ	0.261**	0.260**	0.268**	0.270**	−1.953	−1.889	−1.918	−1.851
	(2.066)	(2.351)	(2.736)	(2.419)	(−1.152)	(−0.960)	(−1.083)	(−0.903)
λ	−0.167**	−0.190**	−0.189**	−0.175**	1.122	1.084	1.100	1.062
	(−2.244)	(−2.866)	(−2.986)	(−2.629)	(1.140)	(0.948)	(1.068)	(0.893)
ω	0.038**	0.031**	0.035**	0.032**	0.274	0.275	0.279	0.264
	(2.128)	(2.408)	(2.324)	(2.472)	(0.495)	(0.495)	(0.501)	(0.435)
α	0.053**	0.060**	0.056**	0.060**	0.039*	0.040	0.040*	0.040
	(5.496)	(7.209)	(6.486)	(7.322)	(1.702)	(1.622)	(1.694)	(1.462)
β	0.937	0.933**	0.935**	0.933**	0.863**	0.862**	0.861**	0.867**
	(74.25)	(96.86)	(85.74)	(97.23)	(4.726)	(4.215)	(4.691)	(3.848)
ν	–	8.132*	1.484**	9.162**	–	61.18	1.898**	55.30
		(7.146)	(25.52)	(6.560)		(0.560)	(8.905)	(0.190)
$\ln(\xi)$	–	–	–	0.116**	–	–	–	0.025
				(4.516)				(0.331)
Log-lik.	−5940.61	−5898.28	−5904.21	−5888.81	−960.56	−960.45	−960.43	−960.38
$Q(20)$	29.40	29.42	29.57	29.32	14.97	14.94	14.95	14.90
$Q^2(20)$	6.989	7.672	7.248	7.796	20.21	20.02	20.14	19.92

Numbers in parentheses represent t values.
**Significant at the 5% level. ***Significant at the 10% level.

the distributions, whereas for β, they are statistically significant for all distributions. For ν, the degrees of freedom, the results are not statistically significant in the case of the t distribution and the skewed-Student t distribution. However, for the GED, the estimated value of ν is statistically significant at 1.898, which satisfies $\nu<2$. Also, the estimated value of the asymmetric parameter $\ln(\xi)$ is not statistically significant.

Next, we diagnose whether the GARCH-M model formulation is correct using the Ljung–Box Q statistic. In Table 4, $Q(20)$ and $Q^2(20)$ represent the Ljung–Box Q statistics of the standardized residuals ($\hat{\epsilon}\hat{\sigma}^{-1}$) and their squares up to order 20, respectively. Here, we asymptotically follow the χ^2 distribution with 20 degrees of freedom. No statistically significant estimates are available for the GARCH-M model. For all $Q(20)$ and $Q^2(20)$ values, the null hypothesis cannot be rejected even at the 10% significance level. From this we can see that the GARCH-M model captures the autocorrelation of the volatility of the ChiNext Board Index.

The empirical results of the MGARCH model are summarized in Table 5. The parameter ϱ, which is the dynamic conditional correlation coefficient, has a statistically significant negative value of −0.786 for the ChiNext and the SZCOMP. This verifies that there is a high negative dynamic conditional correlation between the ChiNext and the SZCOMP. The results for the STAR50 and the SHCOMP are statistically significant with a positive value of 0.650. Contrary to the Shenzhen stock market, a positive conditional dynamic correlation was obtained between the STAR50 and the SHCOMP.

Table 5: Parameter estimation results for the DCC-GARCH model

	ChiNext	SZCOMP	Corr.	STAR50	SHCOMP	Corr.
μ	−0.023	0.028	−	−0.041	0.007	−
	(−0.735)	(2.351)		(−0.541)	(0.170)	
ω	0.056**	0.046**	−	0.144	0.063	−
	(3.616)	(3.082)		(1.318)	(0.682)	
α	0.065**	0.060**	0.036**	0.067**	0.063	0.025***
	(5.995)	(4.632)	(3.384)	(2.455)	(1.248)	(1.918)
β	0.919	0.920**	0.963**	0.884**	0.873**	0.912**
	(70.50)	(54.07)	(87.85)	(15.99)	(6.431)	(23.24)
ϱ	−	−	−0.786**	−	−	0.650**
			(−6.517)			(17.58)
Log-lik.		−8427.67			−1514.51	
$Q(20)$	36.59	45.62	−	14.07	9.990	−
$Q^2(20)$	11.22	21.05	−	15.49	14.92	−

Numbers in parentheses represent t values.

**Significant at the 5% level. ***Significant at the 10% level.

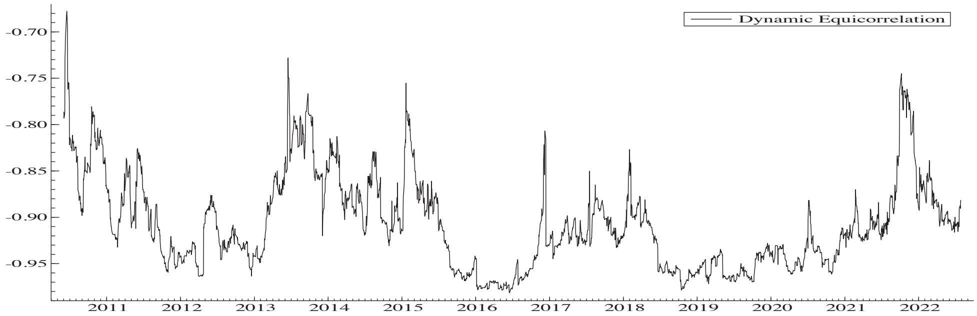

Figure 9: DCC for the ChiNext and the SZCOMP (June 3, 2010 – July 29, 2022)

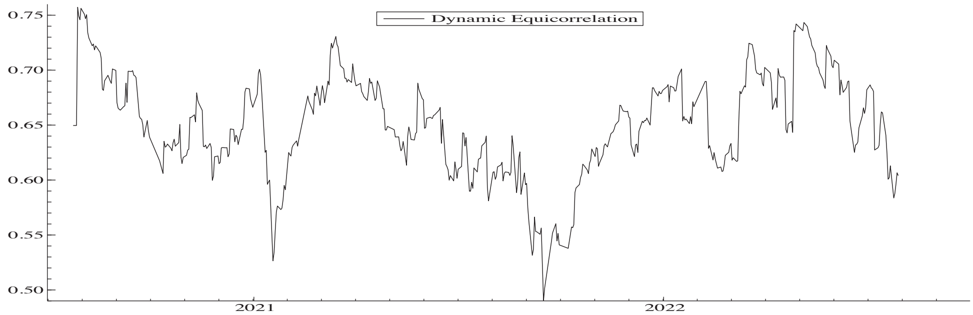

Figure 10: DCC for the STAR50 and the SHCOMP (July 24, 2020 – July 29, 2022)

5 Conclusions and Future Issues

In this study, the time series characteristics of the stock price indices in the growth Chinese stock markets established in mainland China were clarified. As a result of an empirical analysis, the GARCH-M model revealed that the ChiNext Board Index has the same stock price index time series characteristics as shown in previous studies. In the analysis using the MGARCH model, a negative value was obtained for the dynamic conditional correlation between the ChiNext Board Index and the Shenzhen Composite Index in the Shenzhen stock market. On the other hand, for the Shanghai stock market, a positive value was obtained for the dynamic conditional correlation between the STAR50 and the Shanghai Composite Index.

Future tasks include comparing the characteristics of time series using stock price indices of other growth markets such as the NASDAQ in the U.S. and the Growth Market in Japan, and analyzing other models that capture the nature of price fluctuations of risk assets, such as the Markov-switching model and stochastic volatility models, using these time series models.

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